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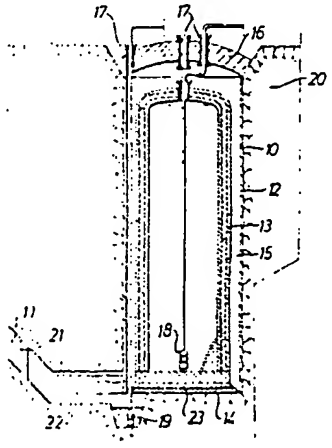
(54) **Explosion-proof plant for the storage of liquid gas.**

(57) A plant for storing liquids at low temperature, with one or more heat insulated, single or double-walled storage tanks under ground.

In order to make the plant safe against explosions and fire while maintaining installation and maintenance costs low, the tank(-s) is located in a shaft (10) under a dome like concrete barrier (16) designed to resist an external shock wave pressure and provided with maintenance passages (17) which are protected against shock waves and flame penetration.

Fig. 1



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Explosion-proof plant for the storage of liquid gas

The present invention relates to a plant for the storage of liquids at low temperatures, such as liquid natural gas, with at least one storage tank located in the ground.

Existing tanks for liquid gas, located in the ground, have roofs dimensioned for low internal pressures and for external load of wind and snow, etc. The roofs are formed of steel or are a thin shell of concrete standing on the tank wall. Upon an explosion or a fire within or adjacent such a tank there is a large risk for the roof falling in, whereby the stored liquid gas will vaporize and cause an expanding high-energy cloud of gas, causing further explosions and fires, which may have a catastrophic influence on a terminal consisting of a group of tanks of conventional type located in the ground.

One object of the present invention is to provide a plant of the kind mentioned initially, which is protected against damages from bomb and gas explosions, and against fire on and above the ground surface. Specifically the invention aims to solve the problem to attain this object with measures causing a reasonable additional cost and not making the inspection and maintenance of the plant more difficult.

According to the invention a plant for storing liquids at low temperature, particularly liquid natural gas, comprises at least one heat insulated, single or double-walled storage tank of steel, metal or concrete located in a shaft of generally uniform cross section in the ground under a generally dome like concrete barrier designed to resist an external shock wave pressure from a bomb or exploding gas and provided with passages for air, personnel transports, electric cables, and tubes for gas and liquids

and protected against shock waves and flame penetration.

Thus, according to the invention a fire and explosion-proof storage plant is provided by means of a heat insulated, single or double-wall storage tank in a shaft in the ground and a barrier in the form of a concrete dome thereover. The dome should be designed so as to resist the pressure of about 1,5 to 5 Mpa caused by a shock wave reflected against the dome from a gas exploding above the ground surface. In addition, this barrier is provided with shock wave proof passages required for the operation of the storage, which are formed so as to prevent also flame penetration and gas penetration. If necessary, the ground around the abutment of the barrier and the walls of the shaft are also sealed against shock waves and gas. The storage tank in a plant designed in this manner is simultaneously protected against bomb attacks.

The invention will be described more closely below with reference to embodiments illustrated on the attached drawing, on which Figures 1 and 2 are cross sections through one each of said embodiments.

The same or similar details of the two embodiments have been provided with the same reference numerals on the drawing.

Figure 1 shows a shaft 10 of generally uniform cross section in rock, which has been blasted by means of a working drift 11 from the ground surface. The shaft may,e.g., have a diameter of 20 to 25 m and be 80 m deep. The walls of the shaft are sealed and reinforced by means of sprayed concrete 12. In the shaft there is provided a heat insulated, double-walled liquid gas storing steel tank 13 on a foundation 14 on the shaft bottom. The storage volume of the tank is 15,000 to 20,000 m^3 at the size of the shaft indicated. Between the external wall of the storage tank and the shaft there is a passable space 15. The space 15

is provided for inspection and maintenance and for this purpose an elevator device, not shown, may be movable in said space.

Above the shaft a barrier 16 in the form of a concrete dome is provided, which is safe against external shock waves from exploding gas. Because of the dome shape of the barrier 16, with convex surface facing up, and concave surface facing down, the barrier is especially resistant to downwardly directed shock forces.

The dome has a substantial curvature, having a radius approximately equal to the diameter of the shaft in which it is installed, as shown by the drawing. The barrier thickness in a 25 to 30 meter diameter shaft may be in the order of two meters. The resistance to shock forces is enhanced by the feature that the dome is supported and anchored upon outwardly flared portions of the shaft wall at the upper edges thereof as shown in the drawing. The concrete barrier 16 also comprises shock wave proof wall passages 17, which are adapted to allow in a convenient manner the introduction of conduits, transport of personnel and raising and lowering of immersion-proof pumps such as a pump 18 for the contents of the tank and a pump 19 for seepage water. The wall passages 17, may, e.g., consist of flanged steel tubes of suitable dimension, provided with a top cover, which is also dimensioned for the purpose intended.

The rock 20 around the abutment of the barrier, the region around the aperture of the shaft 10, is injected with concrete or plastics for sealing against pressure waves. In the working shaft a concrete barrier 21 is provided for protection against the pressure waves. In connection with the shaft a storage 22 for seepage water is provided, in which the pump 19 is used. In order to avoid serious disturbances in the natural temperature distribution around the shaft, caused by the low temperature of the contents in the tank 12, various measures may be taken. Thus, electric

heating cables located in tubes, indicated at 23, which are embedded in the foundation of the tank, may be used as well as similar electric heating cables, not shown more closely, in connection with the shaft walls around the tank. The temperature in the space around the storage tank may be controlled further by pumping of cold air from the bottom of the space and supplying ambient air to the top of the space. This may be performed in a manner known to a person skilled in the art by means of suitable tubing and fan devices.

The embodiment according to Figure 2 differs from the one illustrated in Figure 1 by the shaft 10 being lined by a waterproof concrete container 24. The container 24 has a base plate 25, which is securely anchored in the shaft by means of engagement at 26 into the shaft wall. The container 24 further has a sliding form cast concrete wall 27, the space between the concrete wall 27 and the shaft wall being filled with draining coarse gravel 28. In addition, the storage tank 19 has a cantilever bottom 29 and is standing on the base plate 25 by means of support legs 30, the roof 31 of the tank abutting the lower side of the barrier. As an alternative the tank may be suspended from the overlying barrier 16, in a manner not shown.

A number of additional embodiments of the invention are also possible, comprising larger or smaller modifications of the embodiments as described above. Thus, in the embodiment of Figures 1 and 2 resistance against gas explosions from the underlying shaft may be achieved by means of one or more of a number of possible measures, such as a suitable design and dimensioning of the barrier, the anchoring thereof, and/or loading the top side thereof in a suitable manner. For the latter purpose rock waste may be a possibility.

In order to reduce the risk of explosion the space

around the storage tank may further be filled with an inert gas, such as nitrogen, which is maintained at such a pressure that supply of air from outside is impossible. Convenient means for this, including a gas supply and pressure responsive valve means, are evident to a person skilled in the art.

A plurality of storage tanks may further be provided in one common shaft or in the shaft and side chambers connected therewith under the same barrier.

During operation of the plant it might be necessary to lower or lift pumps or measuring devices in the tank via a connection piece in the roof of the tank and a corresponding wall passage in the barrier. It is then desirable, in the embodiment according to Figure 1, to avoid that upon opening of the connecting piece the cold gas will flow out, with the accompanying disadvantages, easily understood. This aim may be achieved in a simple and reliable manner if the connecting piece in question in the tank roof is connected with the overlying wall passage in the barrier by means of a gas tight bellows like sleeve of rubber or other elastic material.

Further, the barrier may preferably be heat insulated and the wall passages provided with temperature controlling devices, such as cooling tubes and electric heating cables, which are brought into operation upon fire and temporary excess charge of cold gas.

Claims.

1. A plant for storing liquids at low temperature, particularly liquid natural gas, with at least one heat insulated, single or double-walled storage tank of steel, metal or concrete (13) located under ground, c h a r a c - t e r i z e d in that the tank(-s) is located in a shaft (10) of generally uniform cross section in the ground under a generally dome like concrete barrier (16) designed to resist an external shock wave pressure from a bomb or exploding gas and provided with passages (17) for air, personnel transports, electric cables, and tubes for gas and liquids and protected against shock waves and flame penetration.

2. A plant as claimed in claim 1, wherein said concrete barrier (16) is supported and anchored upon outwardly flared portions of the shaft wall at the upper edges thereof.

3. A plant as claimed in claims 1 or 2, wherein the region (20) around the aperture of the shaft in connection with the barrier, and the walls of the shaft, are sealed against shock waves and gas by means of injection or coating (12) with plastics or concrete and that working drifts (11), if any, are provided with shock wave proof barriers (21).

4. A plant as claimed in any of claims 1 - 3, wherein the barrier is heat insulated and that the passages comprise temperature controlling means, such as cooling tubes and electric heating cables, so as to resist fire and temporary excess charge of cold gas.

5. A plant as claimed in any of claims 1 - 4, wherein the shaft is lined with a waterproof concrete container (24), which is free standing or cast against the shaft wall and in which the storage tank is provided.

6. A plant as claimed in any of claims 1 - 5, wherein the storage tank has a circular cross section and a height, which is considerably larger than the diameter.

7. A plant as claimed in any of claims 1 - 6, wherein the storage tank has a cantilever bottom (29) and either is suspended by means of struts from the overlying barrier or by means of supporting legs (30) is standing on the bottom of the shaft or the concrete container.

8. A plant as claimed in any of claims 1 - 7, wherein the barrier is adapted to resist gas explosions from the underlying shaft.

9. A plant as claimed in any of claims 1 - 8, wherein a plurality of storage tanks are provided in the shaft, or in the shaft and side chambers thereof below the same barrier.

10. A plant as claimed in any of claims 1 - 9, comprising means enabling the connection of a connecting piece in the tank roof to an overlying wall passage in the barrier by means of a gas tight sleeve of rubber or other elastic material, through which pump and measuring means can be lifted or lowered.

Fig.1

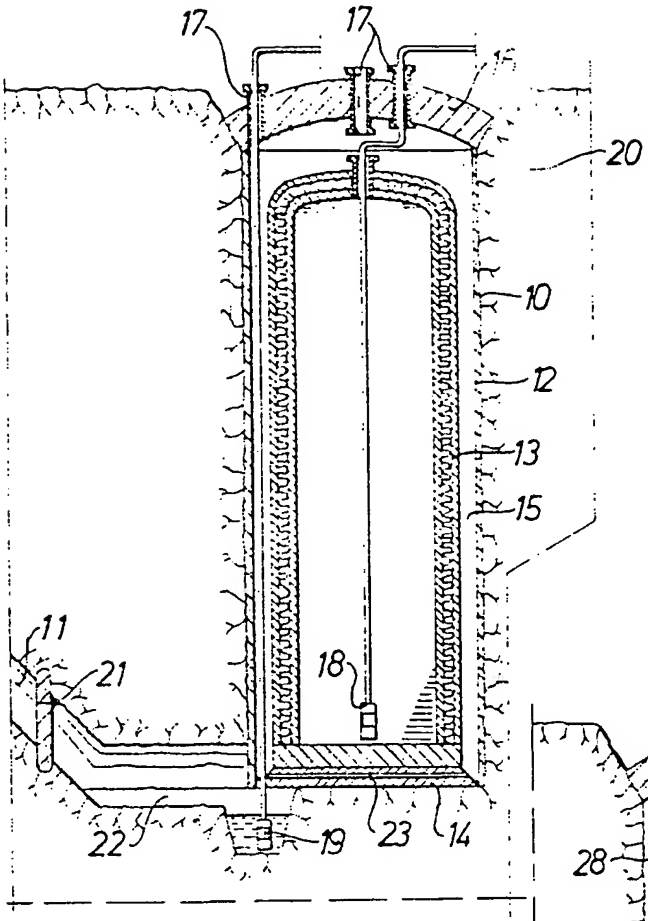

Fig.2